

REPORT

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PROGRAM FOR TRANSFER RESEARCH AND IMPACT STUDIES

Semiannual Report: 1 July 1972-31 December 1972

Contract NASW-2362

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DENVER RESEARCH INSTITUTE
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PROGRAM FOR TRANSFER RESEARCH AND IMPACT STUDIES

SEMIANNUAL REPORT

1 July 1972 - 31 December 1972

- Prepared for -

The Technology Utilization Office
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National Aeronautics and Space Administration

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REPORT HIGHLIGHTS

- Research activities conducted under the Program for Transfer Research and Impact Studies (TRIS) during 1972 included:

Preparation of 10,196 TSP requests for TRIS application analysis;

Questionnaire follow up of 5,444 TSP requesters;

Interviews with over 500 individuals concerning the technical, economic, and social impacts of NASA-generated technology;

Preparation of 38 new technology transfer example files and 101 new transfer cases;

Review of 1,476 NASA-related newspaper and magazine clippings;

Distribution of a bimonthly newsletter; and

Maintenance of a technology transfer library containing more than 2,900 titles (Section I).

- Six different modes of technology utilization illustrate the pervasiveness of the transfer and diffusion of aerospace innovations. These modes also provide a basis for distinguishing the unique characteristics of the NASA Technology Utilization Program (Section II).
- An examination of the ways in which NASA-generated technology is contributing to beneficial social change in five major areas of human concern--health, environment, safety, transportation, and communication--was conducted in 1972 (Section III).

SECTION I. TRIS RESEARCH ACTIVITIES: JULY-DECEMBER 1972

Research activities conducted under the Program for Transfer Research and Impact Studies (TRIS) during the period of July 1 through December 31, 1972 are reviewed in this section.

Tech Brief-Technical Support Package Program

During the second half of 1972, TRIS received 4,183 requests for Technical Support Packages (TSP's) that had been sent to the NASA field centers by persons seeking additional information on technology described in NASA Tech Briefs. This brought the total number of cases processed into the data bank since November 1967 to 84,970; more than 98 percent of these cases were initiated by TSP requests. As Figure 1-1 illustrates, the number of TSP requests received during the latter half of 1972 reflects a sharp decrease from the 13,190 requests received during the same time period in 1971.

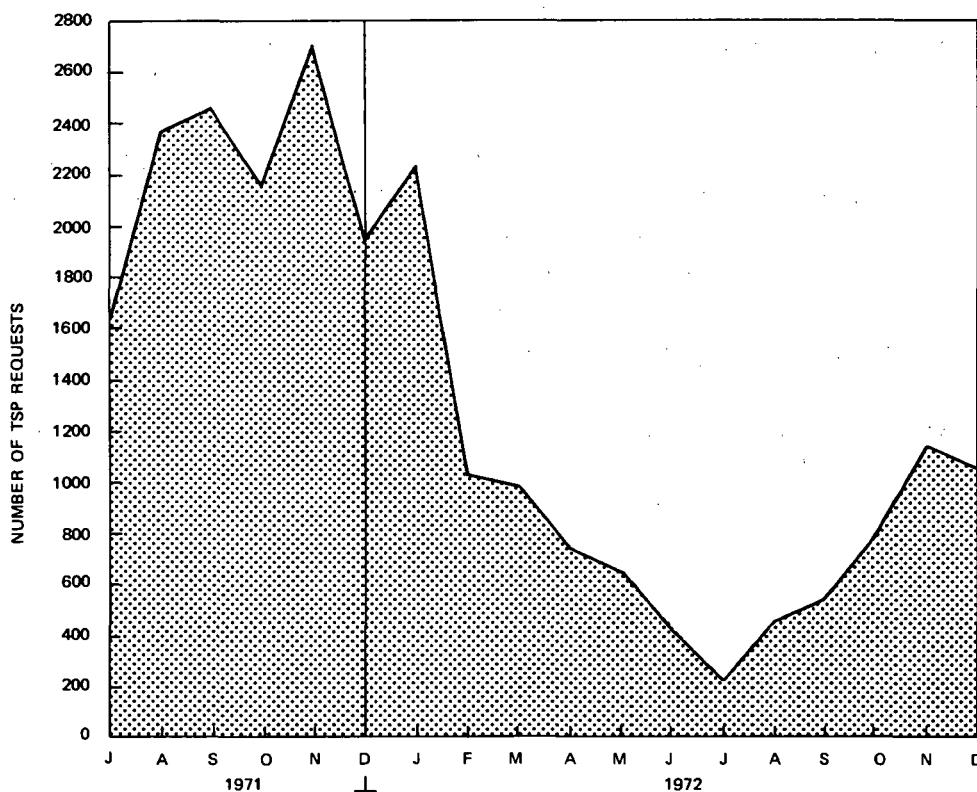


Figure 1-1. Monthly Requests for Technical Support Packages:
July 1971 - December 1972.

In observing the decline in TSP requests indicated in the above figure, it should be noted that the 1972 data (a total of 10,196 requests) represent only those TSP requests that resulted from one Technology Utilization (TU) Program dissemination mechanism for Tech Brief information, the normal Tech Brief distribution system. Whereas for 1971, the data also include TSP requests that were generated by the Small Business Administration's (SBA) announcement of Tech Brief-TSP information in Commerce Business Daily (CBD)--more than one-half of the 26,121 requests processed by TRIS in 1971.

Prior to 1972, the CBD requests were forwarded to the field centers and combined with the TSP requests generated through normal Tech Brief distribution; all of the TSP request information was then sent to TRIS for inclusion in the data bank. Beginning in 1972, the CBD requests were forwarded to the NASA Scientific and Technical Information Facility where they were combined with the TSP requests resulting from two other communication mechanisms--TU Compilations and SBA brochures--in a new computerized system for the management of these TSP requests and field center response. Thus, the number of TSP requests entered in the TRIS data bank declined, as was illustrated above in Figure 1-1.

Although the TRIS data bank did not include TSP request data for TU Compilations, SBA brochures, and CBD announcements, these three new mechanisms generated more than 84,000 requests for TSP's in 1972. While the volume of technical information disseminated by the NASA field centers in 1972 increased substantially over previous years, the number of TSP recipients involved in TRIS transfer documentation activities decreased (see Figure 1-2). In each of the three time periods illustrated in the figure, the shaded areas represent the proportion of TSP requests included in the TRIS data bank and, therefore, involved in TRIS application analysis.

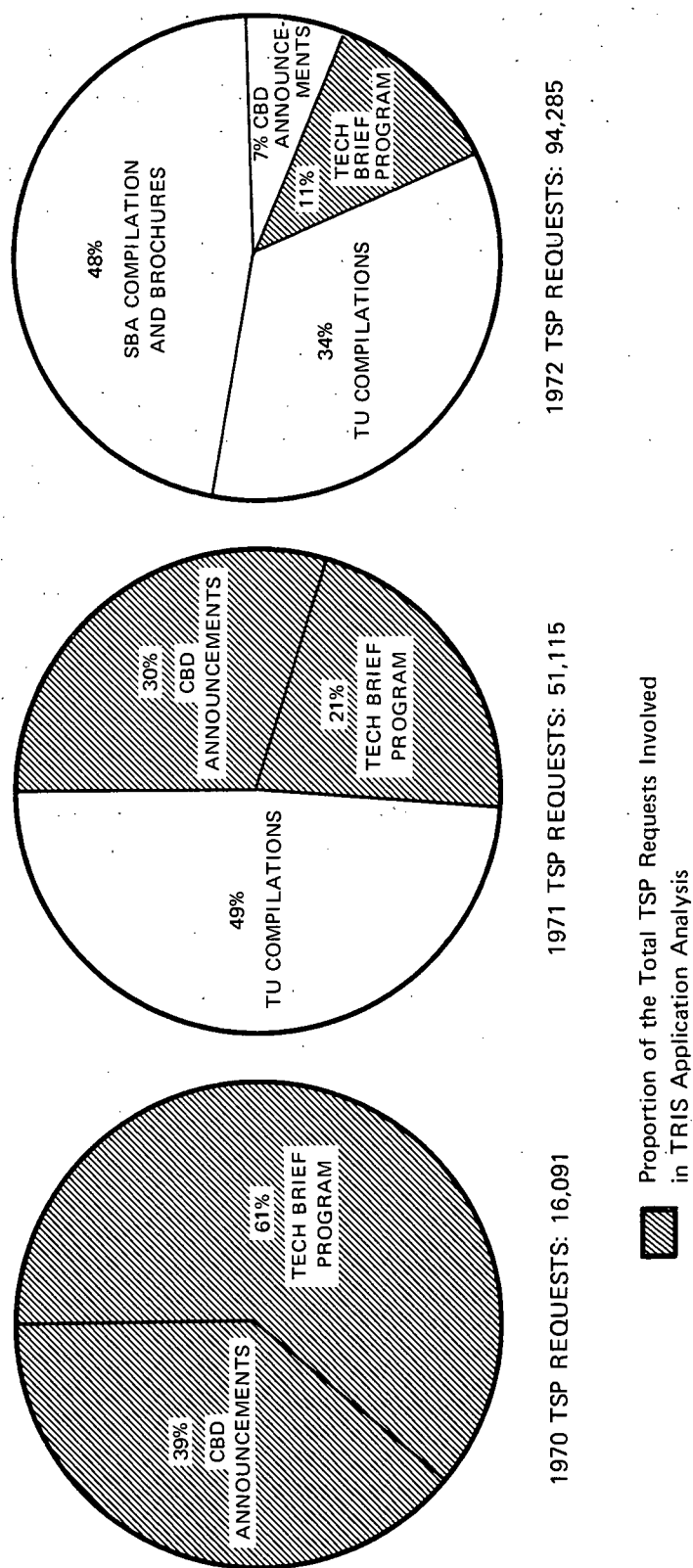


Figure 1-2. A Comparison, by Year, of the Total TSP Requests and Their Origin.

As Figure 1-2 illustrates, in 1970 all TSP requests were entered into the data bank; whereas in 1972, only 11 percent of all known TSP recipients were involved in the TRIS follow-up program. Except in terms of volume, then, the transfer effectiveness of these new mechanisms has not yet been determined. A more detailed discussion of these new mechanisms and how they are influencing program participation by the nonaerospace community is presented in Section II of TRIS Semiannual Report: 1 January-30 June 1972 (November 1972).

Transfer Documentation Activities

In order to obtain information concerning application activities associated with the use of NASA-generated technology, questionnaires are mailed to TSP requesters six months following the date of their request. This delay is considered sufficient time to allow TSP users to reach tentative conclusions concerning applications for the technologies. In 1972, TRIS distributed 5,444 questionnaires, of which approximately 70 percent were returned.

Respondents who indicated on the questionnaire that they had made substantial progress in their attempts to adapt the aerospace technology were selected for additional contact. During 1972, TRIS personnel conducted over 200 interviews with TSP users. Also, more than 300 additional telephone interviews were completed with individuals in both the aerospace and nonaerospace communities for information relevant to transfer profile development and the direct benefits study.

Direct Benefits Study

Early in 1972, TRIS personnel undertook a special study to facilitate more thoughtful discussion of the civilian aeronautics and space effort by exploring how the achievement of mission objectives has contributed to beneficial changes occurring in selected areas of social concern. This task focused on identifying NASA's role in five areas of major national interest: communication, environmental quality, health care, safety and transportation.

By the end of this reporting period, the five area statements were near completion, with publication scheduled for February 1973. A discussion of this activity is presented in Section III.

Technology Transfer Profiles

The preparation of transfer profiles continued to be a major program effort during the second half of 1972. By the end of December, seven profiles had been published which examined industrial applications of aerospace technology within particular fields of technology-- plastics, lubrication, contamination control, fire safety, cryogenics, nondestructive testing and visual display systems. The latter two profiles and a similar type of report, entitled A Case Study in Technology Utilization: Fracture Mechanics, were published in 1972. In addition, substantial progress was made on a profile dealing with the influence of aerospace technology on the electric power industry, and another case study in the area of industrial products and practices was near completion. A more detailed discussion of profile development is presented in Section II.

Other TRIS Activities

TRIS newsletter. During the second half of 1972, TRIS continued to prepare bimonthly newsletters containing up-to-date information on discrete transfers of space program technology. Four editions of the newsletter had been distributed to Technology Utilization Officers at the different NASA field centers and to the program directors of the Regional Dissemination Centers and Application Teams by the end of the year.

Technology transfer example files. Development activities associated with the files continued during this reporting period, both to aid in the preparation of the technology transfer profiles discussed above and to provide interested persons with ready access to descriptions of NASA-related transfer activities. By the end of December, 441 files had been established, containing 898 individual transfer cases; 38 files and 101 new cases were added to the system in 1972. In addition, 171 files had been updated one or more times over the past 30 months, including the preparation of comprehensive file summaries. These summaries describe the space program technology and its role in meeting mission objectives; then, they present one or more examples of how different organizations or individuals in the nonaerospace community have used the technology.

NASA-related news clippings. Throughout this reporting period, TRIS personnel continued to review news items taken from selected

magazines and newspapers distributed in the United States and Canada. The clippings, which expand the program's sources of leads to technology transfer activities, were compiled for NASA's Technology Utilization Office by a professional clipping service. In 1972, TRIS processed a total of 1,476 news items, taken from 585 individual publications, that referenced space program activities and technology. Those items which indicated transfer activity were selected for follow-up and, subsequently, were included in the transfer example files. In some cases, the clippings were used in preparing transfer profiles or direct benefits statements.

Technology transfer library. The collection in the library increased to more than 2,900 titles by the end of 1972.

SECTION II. TECHNOLOGY TRANSFER PROFILES

Transfer of information is an inseparable part of research and development. All those concerned with research and development . . . must accept responsibility for the transfer of information in the same degree and spirit that they accept responsibility for research and development itself.¹

The primary output of TRIS during this six-month reporting period continued to be the technology transfer profiles. Two new reports were prepared--Visual Display Systems and Industrial Products and Practices--which contributed to understanding how technology created originally for NASA purposes is adapted and applied to non-NASA problems.

The secondary utilization of R&D results occurs in many specific ways, and there have been several attempts to describe this aggregate activity. Almost all of these efforts are inadequate when applied to NASA's experience because they fail to recognize the single, unique feature of the NASA Technology Utilization Program: namely, that it provides access to the technology for individuals and firms who are in no way aligned with NASA or its missions.

When considering the broad issue of secondary utilization of NASA technology, the following paradigm is useful. Consider the aggregate U. S. industrial activity² being bounded by the large circle in Figure 2-1, with aerospace R&D being central to the figure.

¹U. S. President, President's Science Advisory Committee, Science, Government, and Information; The Responsibilities of the Technical Community and the Government in the Transfer of Information (Washington: U. S. Government Printing Office, 1963), p. 1.

²This model does not incorporate direct transfer to the public sector.

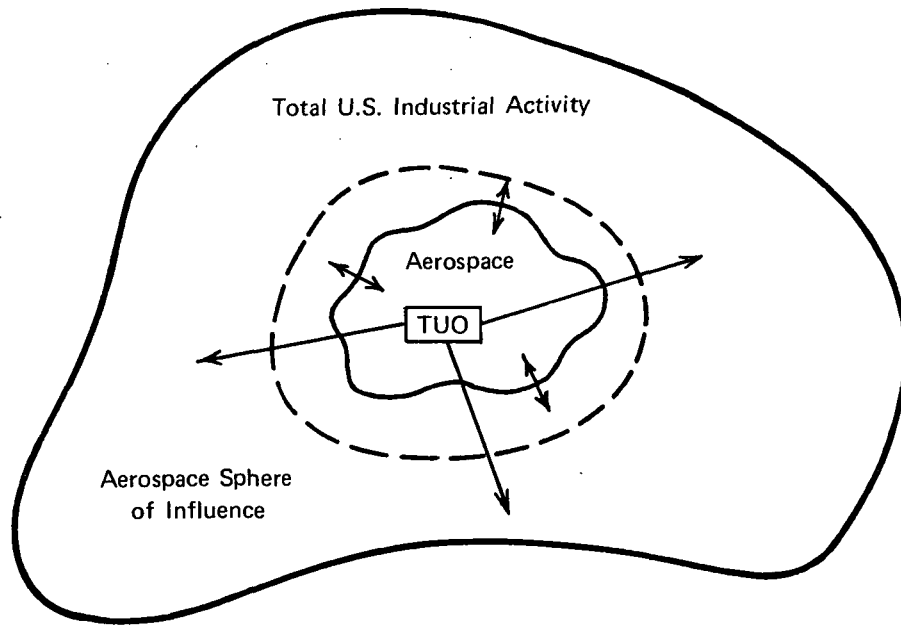


Figure 2-1. Modes of Secondary Utilization

The characteristic activities implied by each arrow linking NASA to firms outside aerospace are different:

- Firms have varying degrees of technological alignment with aerospace, and their relative alignment is of primary importance in effecting secondary utilization.
- Increased distance from the aerospace sector (less alignment with aerospace) decreases the likelihood and subsequent impact of utilization.
- Increased distance from the aerospace sector implies that a stronger effort is required to achieve impact.

Basically, there are two kinds of utilization activity illustrated in the figure: technology diffusion and technology transfer. Diffusion is suggested by the short arrows indicating the movement of technology between aerospace and its attendant sphere of influences. For diffusion, the movement of aerospace technology is not unlike that of technology movement in other sectors. In agriculture, for example, the U. S. Department of Agriculture spent over \$349 million for research and development activities during 1972. The information generated by

agricultural research programs in the U. S. is disseminated by the Office of Information and the Cooperative Extension Service through publications, mass media, visual communications, and interpersonal contact. Similar diffusion activities are facilitated by the NASA Scientific and Technical Information Office, the Defense Documentation Center, professional activities of aerospace scientists and engineers, people movements, and parallel marketing strategies of industrial firms.

Technology diffusion can be contrasted with technology transfer, as implemented by the NASA Technology Utilization (TU) Office, in that individuals who would not otherwise have access to aerospace technology are made aware of the inventions and innovations resulting from aerospace research. Table 2-1 presents some of the contrasting characteristics of diffusion and transfer.

TABLE 2-1. CONTRASTING CHARACTERISTICS OF
TECHNOLOGY DIFFUSION AND TECHNOLOGY TRANSFER
AS MECHANISMS FOR INTRODUCING NEW TECHNOLOGY

DIFFUSION	TRANSFER
Strong alignment between originator and adopter.	Organizations participating in planned transactions independent of sectoral alignment.
Technological constraints serve as a focus for problem-solving activities.	Application constraints, i. e., economic constraints, serve as a focus for problem-solving activities.
Innovations tend to be institutionalized because they redefine best practice or cause stepwise improvements.	Innovations tend to have transient impact since their application represents a currently <u>optimum</u> alternative: vulnerable to a better solution as time goes by.
Ongoing, interactive communications influence sector performance.	Singular technical communications influence organizational performance.
Additional technological advancement often occurs as adoption proceeds.	Little or no advancement of technology; adaptation is crucial.

It should be noted that diffusion and transfer are distinctive labels for characteristic processes at each end of a continuum of technology movement. While it is often difficult to find examples of "pure" diffusion or "pure" transfer, the distinction is nonetheless useful for sorting out the many manifestations of technology utilization. A number of different modes of secondary utilization can be enumerated and categorized to demonstrate this spectrum of activity. Indeed, at least ten different activities of the TU Office can be identified. The intent here, however, is to be illustrative rather than exhaustive; therefore, the remainder of this section will be devoted to illustrating only selected modes of diffusion and transfer, using examples from the Visual Display Systems and Industrial Products and Practices profiles.

Technology Diffusion

Five of the diffusion modes which exemplify how technology created originally for NASA purposes finds important secondary uses are described below.

Mode I: Diversification by firms that produce for the aerospace sector as well as other commercial or industrial sectors. The focus in Mode I activities is on the application of advanced technical capability, acquired during the conduct of aerospace research, to the development of new or improved commercial products.

Bendix hybrid computer simulation of complex control systems developed originally for NASA's AAP and Skylab Programs was instrumental in the development of electronic fuel injection for automotive engines. Electronic fuel injection eliminates the carburetor, cuts harmful emissions and increases engine efficiency. A simple, computer-like controller monitors combustion temperature and pressure, engine speed, and air flow, then prescribes a precise amount of fuel for each cylinder. The 1972 Volkswagen sedan and squareback models already have electronic fuel injection systems developed by Bendix, and company officials feel that U. S. auto makers will install these systems on their 1974 cars.

Mode II: Development of new technology to promote the direct interest of aerospace programs, with subsequent commercial production occurring because nonaerospace markets are recognized. This mode focuses on the parallel marketing strategies of firms participating in two or more socioeconomic sectors.

Ampex Corporation is now commercializing a new computerized record keeping system that was partially developed under contract to NASA's Marshall Space Flight Center. The original system incorporated the first application of professional broadcast video technology in conjunction with a new tape transport mechanism and a digital address system to direct computer indexing and tape handling. After completing the NASA contract, Ampex continued to develop the system primarily to improve picture resolution. A new division, Videofile Information Systems Division, was subsequently created by Ampex to produce and market the information system. Sales to date have exceeded \$18 million. Purchasers of the system have been the Los Angeles Sheriff's Department, The Royal Canadian Mounted Police, the Illinois Department of Law Enforcement, Southern Pacific Railroad, the Federal Housing Administration, Kings County Hospital (Brooklyn) and two insurance companies.

Contractor activities as illustrated in Modes I and II are an important vehicle for secondary utilization of aerospace technology, since NASA's policy has always been to rely upon contracts with many non-governmental establishments to help accomplish its various missions. Over 90 percent of all funds invested in NASA programs have been spent outside the government; in some years, this has reached 95 percent. These programs have involved about 20,000 industrial prime and subcontractors and suppliers, 200 universities, and, during the peak year of 1965, over 400,000 government and industry workers.

Mode III: The general improvement of industrial practice and product quality through NASA-initiated specifications, standards and special reporting requirements. NASA operates under the philosophy that a failed part is valuable because it represents an opportunity to acquire information for improving products and processes. Failures can also be symptomatic of a larger problem--in which case, similar units may also fail.

In 1964 NASA implemented a warning system to inform all NASA stations and contractors of the existence and nature of component defects. Called the Alert Reporting System it obligates all NASA installations to report "failure, malfunction, or unexpected deterioration (degradation or contamination)" of any part or material "during any phase of its life cycle." Such reports are then widely disseminated to contractors in order to avoid or minimize the recurrence of the problems and to improve equipment reliability.

In 1969 a major semiconductor manufacturer was notified that an Alert was forthcoming, and certain faulty semiconductors were being returned. Failure analysis had disclosed the presence of nickel particles inside the protective metal case. Following issuance of the Alert, the semiconductor manufacturer conducted a worldwide search for a supplier who would cooperate in devising better case manufacturing methods. In addition, the firm further improved its own case preparation procedures by implementing an automated chemical, mechanical, and solvent rinse cleaning process. Beyond these measures, the company added another process step into its semiconductor production: passivation of the entire die surface. This process yields a minute glass-like coating over the surface to insulate effectively the conductive elements from any contamination inside the case. The added steps of depositing the coating and opening holes for external leads were expensive, possibly increasing production costs by eight to forty percent, depending on the item. Nonetheless, the gain in reliability was deemed more important than the cost increment, and the passivation process was implemented for most of the firm's output of several million items per day for commercial as well as government markets.

While individual manufacturers may have expertise in a specific kind of failure analysis, they have no compelling reason to share that knowledge with others. NASA, on the other hand, has published a comprehensive compendium (NASA CR-114391) of failure analysis procedures, case histories of failed parts, and recommendations for industrial applications.

Mode IV: Intersectoral diffusion of R&D results through the professional alignment of diversified socioeconomic interests. The commonality of technical interest provides one of the most powerful mechanisms for diffusion, because professionals from different economic sectors rapidly share in the technical advances of their colleagues. For example, interest in remote sensing serves to link technologists from the fields of agriculture, forestry, geography, cartography, hydrology, geology, oceanography, environmental quality and many others. While remote sensing involves much more than satellite-based observations, the space program has provided the opportunity to view the earth more comprehensively than ever before. This unique capability was crystallized in July 1972 when NASA launched the Earth Resources Technology Satellite (ERTS)--the first satellite devoted exclusively to the study of the earth and its resources.

The ability to distinguish between healthy and dead or dying vegetation in ERTS images provides a new way to assess hazards from fires, says Robert N. Colwell of the University of California, Berkeley. Photographs of the Oakland-Berkeley area, he notes, show clearly the more than 1,200 hectares of eucalyptus trees that were destroyed by a 9-day period of freezing weather in December 1972. They also reveal that the current rainy season is producing a record growth of grass vegetation on the range and park lands intermingled with the eucalyptus forests. This grass will dry out next summer and, in combination with the dead trees, present a tremendous fire hazard to homes in the area. Armed with data from ERTS and ground surveys, area officials are seeking \$4 million in federal and state disaster aid loans to reduce the fire hazard.³

NASA's Goddard Space Flight Center prepares a computer index of all ERTS photographs as well as thousands of samples on 16-millimeter microfilm. Some 300 NASA-funded research groups in countries

³"ERTS(II): A New Way of Viewing the Earth," Science, CLXXIX (April 13, 1973), 171.

throughout the world receive selected ERTS images for a wide variety of developmental purposes directly from Goddard.

Mode V: Relocation of skilled individuals from aerospace to other economic sectors, with the subsequent promulgation of aerospace technology to solve analogous problems. Since 1960, an entirely new technical field--contamination control--has been created to help satisfy the demanding reliability requirements in the aerospace and atomic energy industries. NASA, AEC, and the Department of Defense were instrumental in this classic example of new demands converting an old art into a new science. Although the art of contamination control had been practiced for many years in hospitals and industries such as food processing and pharmaceuticals, the intensive federal R&D programs of the last two decades have helped create today's contamination control industry, complete with its own equipment manufacturers, professional societies, and an integrated technological base. The experts and manufacturers that comprise the contamination control industry are now diversifying to satisfy growing demands for better product quality and public health in other sectors of the American economy.

Ronald R. Hite developed his contamination control expertise while working for the Hughes Aircraft Company. In 1967 he also helped prepare the Contamination Control Handbook (NASA SP-5076). In 1968 Hite joined the staff of Scientific Data Systems, Incorporated, as a contamination control expert. The company, now called Xerox Data Systems, manufactures computer peripheral equipment such as disc file memories and tape drives. Since joining the company, Hite has used his experience to make several improvements in the control of contamination in the company's production facilities, including faster and more thorough cleaning techniques, cheaper equipment to achieve the same or higher cleanliness standards, additional clean work stations, and improved monitoring of contamination control equipment. As a direct result of these improvements, Xerox Data Systems has significantly reduced the failure rate of finished products, increased the production rate, and reduced the overhead costs for contamination control equipment and operation.

Technology Transfer

In the elaboration of the various modes for technology utilization presented thus far, there has been a common element: the adoptor has been aligned with the aerospace sector, either technically or contractually. But how does a firm participate in the gains from aerospace research and development without being aligned with that sector?

The Technology Utilization Office operates various programs to effect the transfer of aerospace technology. In addition to its publishing program, which has several different forms, there is a program which links business and industry directly with the store of aerospace technology (Regional Dissemination Centers); a program which provides an interface between aerospace and public sector problem areas (Application Teams); and a program which provides adaptive engineering to aid in the solution of public sector problems. These programs can be aggregated under yet another mode of technology utilization--Mode VI.

Mode VI: Public-interest transfer of space program experience to nonaerospace organizations through a planned program linking the NASA/aerospace sector with commercial firms and public sector entities.

A Technical Support Package which describes a method for predicting the biaxial weld strength of welded structures was used for redesigning pipe joints in an Eastman Kodak Company chemical plant. Previously, pressure surges in the chemical piping produced ruptures that created serious safety problems. A design engineer working on the problem requested the NASA document after seeing the Tech Brief. He used the prediction method that was outlined, in conjunction with failure analysis, to develop the pipe designs which were incorporated in a new installation. Plant safety has been significantly improved by eliminating rupture hazards, with relatively little cost to the company.

The five Regional Dissemination Centers (RDC's) created by NASA help users to obtain technical information in packages that are tailored to their specific needs. The RDC's primary information source is a computerized data base of over 800,000 scientific and technical

aerospace reports. This data base is supplemented by abstract services in specific areas such as chemistry, engineering, electronics, plastics and metallurgy. The services of the RDC's can be illustrated in the following transfer case.

Pyronetics, Incorporated was developing a portable, low-cost, multi-purpose welding torch, but was confronted with the problem of a bulky, high pressure oxygen supply. In March 1971, Pyronetics requested a retrospective search of the NASA data bank for information on chlorate candles. These candles are unique in that they generate oxygen while burning. The Western Research Application Center (WESRAC), the NASA RDC located at the University of Southern California, provided information on composition, hazards, applications, manufacturers and shipping regulations. This information was crucial in the development of Pyronetics' new, portable welding torch, which weighs only seven pounds and sells for approximately \$40. By the end of 1972, over 20,000 units had been sold.

The unique characteristic of all program elements of the Technology Utilization Office is that they operate to provide technical assistance for problem-solving; and, furthermore, they represent planned efforts on the part of the Agency to provide assistance to people not normally aligned with the space program.

Conclusion

There is an important insight suggested in the dichotomy between diffusion and transfer. The success of NASA's attempts to provide secondary utilization is often judged in terms of "transfer" impact. This short-sighted viewpoint neglects the enormous amount of activity that is conducted with little fanfare because of a close alignment between NASA technology generators and non-NASA adoptors. A more realistic assessment of the activities of the TU Office must consider its unique mission and the inherent difficulty of providing access to people who have very little in common with NASA and, furthermore, little incentive to tap the reservoir of NASA technology.

SECTION III. AN ANALYSIS OF THE NASA ROLE IN FIVE MAJOR AREAS OF HUMAN CONCERN

An analysis of a highly technical activity such as the civilian aerospace program can be effectively translated into terms which describe its impact on the American public. Nevertheless, the task of communicating with different groups of people about NASA's various missions has become increasingly difficult as interest in other national priorities has come to compete with, and often to overshadow, concern about those missions. Late in 1971, DRI undertook a preliminary study to examine the significance of NASA's mission activities in areas of major national concern. During the course of this study, which continued through 1972, the NASA role in five major areas of human concern was investigated. The overall purpose of this research was to facilitate an evaluation of the Agency's contributions to beneficial social change occurring in those five areas.

Evaluative Methodology

As a means of gaining perspective about the areas of greatest concern to different groups of Americans, a cross section of 27 special interest and general news publications was reviewed. Out of approximately 160 areas of human concern identified in those sources, the following five areas were selected for further analysis: health, environment, safety, transportation and communication. The topics chosen to illustrate NASA's role in each of these selected areas had strong technical components as well as an interface with NASA program objectives. During the course of the study, major emphasis was placed on determining significant changes that have been occurring in each of the areas and on identifying what specific NASA programs contributed directly to such changes. A more detailed discussion of the methodology employed in this study is presented in Project for the Analysis of Technology Transfer: Final Report, July 1972.

Selected NASA Contributions to Beneficial Social Change

The following are just a few instances of beneficial change in five areas of human concern that are accruing from the application of NASA-generated technology.

Health care: expanding the biomedical technical base. NASA programs have made largely unanticipated contributions in upgrading the

quality of health care as well as developing efficient methods to meet the sharply increasing demand for such care. Medical research for space flight and the systematic development of means for remotely acquiring, monitoring, and interpreting data on physiological processes during flight have contributed important technology needed for improving both the quality and quantity of health care. Aerospace technological innovations not only provide the nation with new or improved health care tools, but they also provide greater assistance for more people concerned with maintaining or regaining a healthy condition.

- Scientists at NASA's Ames Research Center, in cooperation with the National Institutes of Health and researchers at Stanford University and the Mayo Clinic, have developed computer techniques to present a visual display of the contracting heart. The computer input is obtained by injecting an X-ray opaque dye into the heart and converting the resulting X-rays into digital data. The new computer technique is being used in selected research centers around the country to evaluate the effects of blocked coronary vessels in heart patients.
- NASA was an early contributor to the technology of automated health screening. At the Manned Spacecraft Center in Houston, for example, a program for the multiphasic analysis of clinical patients has been in operation since the center was established in 1961. This work has affected medical procedures by standardizing results, reproducing tests, defining norms, and developing computer software for records management and data analysis.
- In the field of biomedical instrumentation, several NASA developments have found medical application. Engineers at NASA's Lewis Research Center have designed a control system for an experimental artificial heart operated by the Cleveland Clinic; they also have designed a small, inexpensive analog computer to monitor heart patients' blood pressure and cardiac output in St. Vincent's Charity Hospital in Cleveland.

Environmental quality: the quest for global improvement. Environmental problems in this country and other nations of the world have become alarmingly clear during the past decade. Pollution, severe storms, and diminishing resources are now recognized as matters of global concern which demand technical breakthroughs as well as social and political decisions to implement change. The measurement techniques for determining the starting points and monitoring progress are being rapidly developed with the help of aerospace technology.

- To assess the full impact of pollution, new detection and monitoring equipment and methods have been developed. One example of the use of NASA-developed instrumentation for improving pollution monitoring was recently shown in the Los Angeles Basin. NASA's Langley Research Center participated with the State of California in measuring the spatial and temporal distribution of aerosols in the earth's boundary above Los Angeles. The results of this study will enhance the California Air Resources Board's capabilities to recommend efficient control strategy for aerosols in an effort to reduce health hazards and improve visibility in major urban centers.
- One of the most dramatic benefits accruing from weather satellite programs has been an improved ability to predict severe storms. At Kennedy International Airport in New York, weather personnel annotate satellite photos to show pilots the location of storms, fog, snow and clear weather. Helpful in predicting jet streams, turbulence, and destination weather, the photos thus aid in the more efficient routing of aircraft and in promoting the safety and comfort of passengers.
- The discovery of new energy supplies should help reduce the burden of diminishing reserves currently affecting the country. To this end, an earth resources program, utilizing aircraft and satellites, has been underway since 1968. The NASA overflight program has developed the equipment and techniques needed to recognize geologic formations normally associated with oil and gas deposits.

Safety: protection through prevention. With its heavy involvement in developing manned systems--both aircraft and spacecraft--that are propelled by some of the most volatile chemicals ever developed and operated under maximum stress in hostile environments, NASA has become a major resource to the country in the new orientation toward preventive safety. The NASA role in accident prevention focuses attention on improvements affecting the design and testing of equipment and structures, on new ways of preventing unwanted fires, and on broad-sweeping approaches undertaken by the Agency to prevent accidents.

- During the past decade, the use of computer programs has become an increasingly important tool for engineers in performing more thorough analyses of civil structures and machines. A computer program developed by NASA and managed by the Langley Research Center, known as the NASA Structural Analysis Program (NASTRAN), has been used as the principal design tool for structural analyses of a new 40-story building in Chicago. By combining engineering technology with computer programming, designers have been able to insure more reliably the safety of the structure and to reduce design costs.
- NASA has been directly responsible for generating many important developments in fire safety. Special paints that emit a flame-retarding gas when heat is applied have been studied for years by NASA's Ames Research Center; such paints are being evaluated by the National Association of Home Builders as a means of protecting plastics used in housing construction.
- Since 1968, NASA has supported the operation of the Aerospace Safety Research and Data Institute (ASRDI) at the Lewis Research Center to expedite the flow of technical knowledge from the laboratory and the library to the individual with a safety problem. Among its most remarkable achievements, ASRDI has developed a unique data base management system unparalleled in capability anywhere in the world.

Transportation: improving the alternatives. The country's aerospace program is providing guidance in shaping transportation policy and practice for the future. Admittedly, overcoming certain technological difficulties is only a part of the challenge in developing better transportation systems. Economic, social, and political problems are possibly even more demanding. Yet, NASA's work in three important problem areas--noise pollution, congestion, and aviation safety--is providing improvements and alternatives needed for more satisfactory national transportation systems.

- As the civilian agency charged with aeronautical R&D responsibility, NASA has set its sights high for aircraft noise reduction. One method for reducing community noise is based on research that was conducted at the NASA Ames Research Center. The method reduced community noise approximately 50 percent by keeping an incoming airplane further from the ground for a longer period of time and permitting the final descent to be made at reduced thrust.
- Many of the new challenges of transportation, such as easing highway congestion, have technological underpinnings similar to those of the space program. In Morgantown, West Virginia, for example, the Boeing Company is developing the Personal Rapid Transit (PRT) System. This "people mover" is providing rapid nonstop transit for individual passengers in computer-controlled cars. In developing PRT, Boeing has employed many technologies that had their origins in or were significantly advanced by the civilian aerospace program, including systems safety and reliability and maintainability analysis.
- Building on research initiated by the British in the mid-1950's, NASA has worked with the Department of Transportation and other agencies to solve the problem of airplanes skidding off runways. NASA's Langley Research Center has developed a variety of methods for grooving and roughening runways. Airline pilots who have used these runways report them to be of distinct assistance in stopping and in maintaining runway alignment during inclement weather.

Communication: developing better links among people. New communication technologies bred out of America's civilian aerospace program have contributed directly and substantially to many advances in human communication. Through a unique series of technical accomplishments involving satellites and computers, NASA and the aerospace community have helped open new horizons in the exchange and use of information in such important areas as international relations, medicine, education and weather forecasting.

- o The primary use of communication satellites to date has been in connection with the development of networks for commercial telecommunications among different nations. Since the establishment of the International Telecommunications Satellite (INTELSAT) Consortium in August 1964, the system has grown from the original 14 to 83 member nations. Utilizing satellite technology, INTELSAT provides international television, telegraph, telephone, and data and facsimile services.
- o NASA has been a catalyst in the integration of computers into interactive communication systems. Agency personnel, along with computer contractors, are seeking ways of developing communications networks that streamline the process of acquiring, storing and disseminating documentary information. NASA created the first major market for a Lockheed-developed computerized information system called DIALOG. Under contract, Lockheed modified DIALOG to NASA requirements to produce the NASA/RECON ("remote console") system. This system quickly and easily enables aerospace engineers and scientists to identify potentially useful information in a collection of approximately one million documents. With the success of this interactive communication retrieval system, various versions of NASA/RECON and Lockheed's DIALOG have been adapted for use by other government agencies, including the National Library of Medicine, the Defense Communication Agency, and the Department of Justice.

Conclusion

The areas of human concern which were briefly discussed above conform to a discrete set of selection criteria. The areas were generally familiar to many groups of people and displayed certain desirable social changes. In addition, specific NASA contributions to the technologies involved in achieving beneficial change were easily identifiable.

In many instances, NASA has employed its unique R&D capabilities to help other government agencies solve major problems of human concern. Also, expertise developed by space program contractors has been applied to the solution of many of these problems.

The topics selected for discussion within each of the five areas represent only a handful of the many achievements evolving from the aerospace R&D programs. This brief evaluation of advances made by NASA in contributing to the solution of human problems provides a useful basis for understanding the impact of technology on social change in the nation. As 1972 drew to a close, the results of this research effort were being prepared for publication in five brief statements.